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THE EXPANDING UNIVERSE[1]

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THE considerations on which I am to address you this evening deal with questions which have long been of interest to the more inquisitive of mankind, questions to which answers must have been sought in that dim past in which man became the first animal capable of extended thought. The structure and meaning of that vaster world of heavenly objects gave rise to speculations, many of which have played decisive rôles in the development of civilizations and cultures. The unaided eye of the ancients limited them essentially to conjectures concerning our immediate neighbors, the other members of the solar system, and those less immediate neighbors, principally stars and configurations of stars and nebulosities, which constitute our galactic system. Only within the few centuries characterized by modern science has the telescope enabled man to explore more thoroughly that larger universe of which our own stellar system is but a member and, together with the still more recent development of the spectroscope, enabled him to bring order into apparent chaos. But the final proof that the great nebulae which have been the subject of speculation for three centuries do in fact constitute island universes comparable with our own galaxy has only been obtained within our own age, and the proof of the regularity of their distribution in space and of their relative motions is a result of the research of the past decade. These discoveries have revived old questions in a new form, and I propose this evening to set forth the partial answers which are offered by relativistic cosmology, that offshoot of the general theory of relativity which deals with the structure of the universe as a whole. But let us first briefly review the facts with which we can start and which are to be brought into order.

[1] An address delivered before the ninth annual meeting of the West Virginia Academy of Science at Athens, West Virginia, April 29, 1932.

Astronomical research has shown that our own sun is a relatively unimpressive member of that great galaxy whose lenticular shape is revealed to us, in virtue of our rather central position in it, by that striking band of stars, the Milky Way, which encircles the heavens. Our nearest neighbor, Proxima Centauri, is some four light-years removed, and on the average there is one star in every 350 cubic light-years in our neighborhood. The density of stars decreases as we go out toward the boundary of our galaxy; in any direction in the plane of the Milky Way it drops to one-hundredth of the above value at a distance of about 27,000 light-years, and in directions perpendicular to this plane the same decrease is attained at a distance of 5,000 light-years. Within these limits are a large number of non-stellar objects, such as the globular clusters and the diffuse luminous bodies known as planetary nebulae, but since we are interested here in the universe as a whole and not in the phenomena which occur within the borders of such a closely-knit system as our galaxy we pass on to the great nebulae which may be considered as counterparts of our own system.

The great extra-galactic nebulae are scattered quite uniformly over the celestial sphere, provided we attribute their apparent relative scarcity near the Milky Way to the obscuring effect of matter in our own galaxy. The distances of some of the nearer of these objects can be computed on the hypothesis that certain types of stars which are observed in them are of the same physical constitution as those which are in our own system; the resulting regularity thus found in their actual size and luminosity leads to the hypothesis that the apparent differences in size and brightness observed in this class of objects are due primarily to their distances. One of the nearest and most striking, the great spiral nebula in Andromeda, is estimated by Hubble to be some 800,000 light-years away, and its linear dimensions to be about one half those of our own galaxy. The results of surveys of extra-galactic nebulae, by Hubble at Mt. Wilson and Shapley at Harvard, indicate that although the nebulae often occur in clusters yet on a still larger scale they are fairly uniformly spaced, their average distance apart being somewhat less than 2 million light-years. The faintest of these objects, which can be well observed with the 100-inch telescope at Mt. Wilson, are of about 19th total magnitude, and are accordingly estimated to be at a distance of some 300 million light-years. Hubble estimates that about 30 million nebulae are contained within a sphere of this radius, and that so far as the observations go they are uniformly distributed, much as the molecules of gas in a container, throughout the observable universe.

In order to complete this picture of a universe consisting of nebulae fairly uniformly spaced at distances of 2 million light-years apart a knowledge of their velocities is essential. Now in discussing velocities it is to be remembered that the theory of relativity places an upper limit of 300,000 kilometers per second (the velocity of light) on the velocities of material bodies, but also that we can give no reason why the relative velocities of physically unrelated bodies should not have any value up to this limit. The relative velocities of various members of our own system may be as great as several hundred kilometers per second, but are even so but a small fraction of the limiting velocity. The measurement of velocities of objects as distant as the great nebulae is almost entirely restricted to the radial velocity, that component in the line of sight; this aspect of the motion gives rise to a Doppler effect which can be measured by the spectroscope regardless of the distance of the source, provided only that the source is sufficiently intense. The radial velocities of about 90 nebulae have been determined in this way, and it is found that all but five of these are moving away from us. Furthermore, the more distant the nebula the greater its velocity of recession; it is to be noted that the five exceptions are all our more immediate neighbors and are mainly due to the motions of the sun with respect to the galaxy. This relation between average velocity and distance is one of direct proportionality, the velocity increasing 1,000 kilometers per second for each additional six million light-years. One nebula with a velocity of recession of 19,700 km./sec. has recently been observed, corresponding to a distance of 105 million light-years. These facts indicate that there is, superposed on the relatively small peculiar motions of the nebulae, a velocity of recession which is proportional to distance and which leads to the remarkable conclusion that the universe is expanding at such a rate as to double the distance to any nebula every 1,400 million years.

This evening I wish to trace the steps which have led to an explanation of these startling observations, and I hope to show you that this explanation follows naturally from the general theory of relativity with the aid of a very few reasonable *a priori* assumptions. But let us first review those elements of the relativity theory which are essential to our argument. The Newtonian theory conceived the 4-dimensional continuum of space and time as split up into a 3-dimensional Euclidean space and a universal time which was the same for every observer, regardless of his motion. The matter immersed in such a space-time had no effect on its properties, and the motion of matter was attributed to forces, the principal one of interest at the moment being the universal force of

gravitation. Out of the conflict which grew up between this picture of the world and that of the electromagnetic theory emerged Einstein's special theory of relativity. According to this theory each observer still split up the world of space and time into a Euclidean space and a "local" time, but the manner in which this division took place was dependent on the observer; each chose his reference system in such a way as to be at rest with respect to it. This transition from a geometrical to a kinematical view of space-time left essentially unaltered the status of forces, including that of gravitation. The final step, that from the special to the general theory of relativity, effected a great unification; gravitation was incorporated into the geometry of space-time. Under the general theory the special theory is still valid in any sufficiently limited portion of the space-time universe, but its geometry on a larger scale is determined wholly by the matter which it contains. In this way the brilliant program suggested by Riemann some fifty years before was carried through by Einstein.

With these facts in mind let us now return to the problem of determining the properties of a universe in which matter is, in the large, uniformly distributed in space, ignoring the irregularities in its structure due to the agglomeration of matter into nebulae. But we must first examine in what sense we may speak of a uniform spatial distribution of matter if space as such is relative to the observer in question. Does this mean that we may reinstate a universal time which is of significance to all observers? I believe that it does, within limits, and the justification of this procedure is one of the most important steps in our exposition. The only case in which failing to take account of the difference between the local reference systems of neighboring observers can lead to serious discrepancies is that in which their relative velocity is an appreciable fraction of the velocity of light. But the observations we have set forth indicate that except for relatively unimportant peculiar motions the relative velocities of neighboring nebulae are small compared with this limiting velocity, and hence observers stationed on these nebulae may choose a common reference system without undue warping. We may thus set up a reference system which splits up the universe into a cosmic space and a cosmic time which will serve in any portion of it as a mean local space and mean local time for all the observers concerned. It is to be noted that there is no contradiction between this view of a reference system of universal validity, with respect to which each nebular observer is approximately at rest, and the fact that widely separated nebulae have a considerable relative velocity; we need only refer to the very analogous situation of observers situated at points of given latitude and longitude on an expanding sphere—each of them is at rest with respect to the reference system on the sphere, but their relative distances as measured on the sphere are increasing directly with the radius.

We are now in a position to restate our facts and hypotheses in a form which leads directly to the desired solution. We have introduced a cosmic time in a way which makes significant the statement that the observed distribution of nebulae is spatially uniform, and we assume that this uniformity extends indefinitely beyond the portion of the universe to which we have observational access. (It is to be noted in passing that our procedure is to some extent equivalent to Weyl's assumption that all matter in our universe has always maintained a physical unity, even in the remote past—that the actual universe is not the fortuitous superposition of two or more incoherent parts; only with the aid of this assumption or one equivalent to it can one hope to establish a unique velocity-distance relationship.) But then according to the theory of relativity the geometry of the universe in the large must exhibit the same uniformity as the material content by which it is conditioned, and since in our idealization matter is distributed uniformly throughout cosmic space this latter must itself be homogeneous and isotropic—it must exhibit the same intrinsic properties in every point and in every direction. Now it has been known for almost a century that there are but three types of completely homogeneous and isotropic space possible—Euclidean space, Riemannian space, which may for our purposes be considered as the 3-dimensional analogue of a sphere, and a third type which is due independently to Bolyai and to Lobachevski. These three cases may be characterized by the fact that in the first a unique parallel can be drawn to a straight line from a point not lying on it, in the second none, and in the last an infinity of parallels can be drawn through the point. The theory which we are developing does not enable us to choose between these three alternatives on basis of the observations, and I therefore consider myself at liberty to restrict myself in the following to the case in which cosmic space is characterized by the Riemannian type. Our highly idealized universe is therefore one in which space is the 3-dimensional analogue of a sphere, and is accordingly finite and yet unbounded. Denoting its radius by R, the greatest distance between two points in it is πR and its total volume is $2\pi^2R^3$. The spatial reference system introduced above is the analogue of longitude and latitude on an ordinary sphere, and the distance between two points is equal to R times the angular distance between them. But R is not necessarily independent of time

as it is in some manner determined by the density of matter in the universe, and that density is decreasing in virtue of the observed expansion. In order to determine the rate at which R is increasing we recall that the distance between two nebulae is directly proportional to R and the observed rate at which this distance is increasing is such as to double it in 1,400 million years.

What is the ultimate fate of this expanding bubble of a universe? Will it continue its present rate of expansion until each island universe is completely isolated, or will it eventually cease to expand or even contract? We are here on highy speculative ground, and can only examine the various possibilities which may arise. I mentioned above that the manner in which R varies with time depends in some way on the density of the matter which constitutes the universe, and I shall now review briefly the cases which may arise if we assume the rigorous conservation of energy. It can be shown that this assumption is quite equivalent to the assumption that we are considering the material content of the universe as a gas in which the molecules (*i.e.*, nebulae!) exert no pressure on each other—and this is enough to warn us not to close our minds to other possibilities, for if, for example, we wish to take radiation into account we must also take account of the pressure which it exerts.

We first consider that highly idealized case in which the density of matter is taken as zero—the possibility which results from the assumption that the density of matter is so small as to be without effect on the structure of the universe. This case was considered fifteen years ago by the Dutch astronomer de Sitter, whose name it bears; it, together with the Einstein universe considered below, enjoys the distinction of being "stationary" in the sense that its intrinsic properties are unchanged in time. Here I must make an exception to my agreement to consider only universes in which space is of the Riemannian type, for the space of the de Sitter universe is Euclidean—its radius has become infinite. Nevertheless, each nebula is at the center of a sphere of finite radius R_d which is unchanged in time and which represents an utmost limit beyond which an observer on the nebula can not see. The other nebulae observed within his sphere appear to him to be receding with a speed which is directly proportional to their distance from him, and once they reach the limiting sphere they are forever lost to his observable universe; the space about him is expanding at such a rate that the light from nebulae outside his critical sphere is swept back again. The observations leading to the velocity-distance relation set forth above enable us to set the radius of this observable universe at 2,000 million light-years. But whatever attraction this splendid isolation may have for us, we must turn regretfully from it to other possibilities.

The remaining possibilities for a universe with zero pressure were analyzed ten years ago by the Russian mathematician Friedmann. Although his approach differed in several essential respects from that sketched in the above and although he was unable to give a satisfactory proof that no others existed, we now know that his keen analysis includes all possible cases. The fact that we can not predict precisely the fate of such a universe is due to the appearance of an arbitrary constant λ, Einstein's "cosmological constant," in the equation which determines R in terms of the density of matter. If λ is larger than a certain critical value λ_E, which is inversely proportional to the square of the total mass contained in the universe ($\lambda > \lambda_E = (\pi c^2/2kM)^2$ where c is the velocity of light, k the Newtonian constant of gravitation and M the total mass), it continues to expand without limit, so that evenually all nebulae will be lost to us. This ultimate empty state in which R has become infinite is in fact the de Sitter universe discussed above and we now see that it is stationary because everything worth happening happened long ago! On the other hand, at a finite time in the past such a monotonic universe had a zero radius. We have the choice of assuming that it began at this time as a singular point, or the emotionally more satisfactory one of assuming that our analysis breaks down because of the untenability of our hypotheses at a time when the universe was much smaller—in which case we should probably be able to conclude that it was originally shrinking and, having reached a finite lower limit, began to expand.

The next case we consider, that in which λ is less than this limiting value and yet positive ($0<\lambda<\lambda_E$), offers two possibilities depending on the magnitude of R. If R is greater than a certain critical radius $R_m>0$, which depends on λ, it continues to expand as in the case considered above, and approaches the de Sitter universe. It differs from the previous case in one essential point: at a finite time in the past it had the critical radius R_m, and if we follow it still further back we find that it was originally decreasing. The other possibility is that in which R is less than another critical value R_M, which also depends on λ and which is itself less than R_m. We then find that R increases at an eventually decreasing rate until it reaches the value R_M, at which time it begins to contract. This contraction continues until it reaches the singular state discussed above in which it has zero radius, and if we follow it through this singularity we find that it again increases, only to repeat the cycle. The case in which λ is zero (which Einstein has of late adopted) or negative is qualitatively the

same as that just described; such a universe is periodic, bouncing back and forth between a state of zero radius and one in which $R = R_M$.

I have left to the last the discussion of what are undoubtedly the most interesting of universes with zero pressure, those in which λ is just equal to the critical value λ_E. In this case the two values R_m and R_M of the radius introduced above coincide, and it is possible to have a universe in which R remains at this common value R_E. This universe is the other of the stationary possibilities, and is of considerable historical interest because it is the case first considered by Einstein in 1917; and is the forerunner of all relativistic cosmologies. His general theory of relativity as first formulated did not contain the arbitrary constant λ, which he introduced two years later in order to avoid certain paradoxes associated with infinite space, and since he was interested only in stationary possibilities (the red shift indicating positive velocities of nebulae being as yet not established) he was led directly to the case which now occupies our attention. In this Einstein universe, as it is called, the radius R_E of the universe is inversely proportional to the square root of the density of the matter which it contains, or directly proportional to the total mass M. Hubble's estimate of the density of matter in nebulae (which we have expressed above in terms of the number of nebulae within the limits reached by the 100-inch) leads to the conclusion that its radius R_E is about 90,000 million light-years. This universe has the amusing property of allowing a light signal to pass clear around it—but it takes 550,000 million years! But what if R is not just equal to this critical radius R_E? Suppose it is displaced slightly from this equilibrium radius—will it return to it or deviate still further? The answer is apparent from Friedmann's work, and has recently been proved explicitly by Eddington—the equilibrium condition represented by the Einstein universe is unstable. If R is displaced by any accidental perturbation ever so little toward smaller values it continues to decrease until at the end of a finite time it becomes zero, and if it is displaced toward larger values it continues to increase and approaches the de Sitter state. This latter case, in which $\lambda = \lambda_E$ and R exceeds the critical Einstein radius R_E, has subsequently been discussed in detail by the Belgian Abbè Lemaitre. It has good claim to the special attention which it has received, for it is the only one of Friedmann's universes which has been expanding forever—no matter how far we follow it back we find that it never quite reaches the Einstein equilibrium state.[2]

[2] For the benefit of those who prefer their mathematics undiluted I may point out that the exact relation to which the field equations lead is given by Friedmann's equation (Z. Physik., 10, pp. 377–396, 1922)

$$c(t - t_0) = \pm \int_{R_0}^{R} \left(\frac{x}{A - x + \lambda x^2/3} \right)^{\frac{1}{2}} dx$$

for R as a function of t, where $A = 2/3\sqrt{\lambda_E}$. For those values of R which may actually occur the cubic $P(x, \lambda)$ in x which appears in the denominator of the radical must be non-negative, and the various cases which may arise are classified according to the number and nature of the positive roots of $P(x, \lambda) = 0$. For the critical value $\lambda = \lambda_E$ the cubic has two coincident roots at $x = R_E$; R may therefore remain at this (unstable) critical radius, giving rise to the Einstein universe, or it may, among other possibilities, continually increase without limit, leading to the case considered more fully by Lemaitre. For $\lambda > \lambda_E$ we always have $P \geqq 0$, corresponding to the monotonically increasing world of the first kind. For $0 < \lambda < \lambda_E$ it has two distinct roots $R_M (\lambda) < R_m (\lambda)$ and is positive only for values of x greater than R_m or less than R_M; the former possibility leads to Friedmann's monotonic world of the second kind and the latter, in common with those cases in which $\lambda \leqq 0$ and in which P has but one real root R_M, to a periodic universe.

In a subsequent paper (Z. Physik., 21, pp. 326–332, 1924), Friedmann discussed the possibility of a world in which matter exerts no pressure but in which space is hyperbolic. The fundamental equation for this case is obtained from the above on reversing the sign of x in the cubic, and leads immediately to a monotonic increasing world of the first kind for $\lambda \geqq 0$ and a periodic world for $\lambda < 0$. A world in which space is Euclidean—the equation of which is obtained from the above by dropping the linear term in the denominator—behaves qualitatively in the same way as this hyperbolic case, a possibility which Friedmann seems to have ignored. But the existence of this possibility is apparent from the present approach, which follows an investigation by the author (Proc. Nat. Acad. Sci., 15, pp. 822–829, 1929) in which all possibilities are explicitly indicated. The special monotonic case in which $\lambda = 0$ has more recently been considered in detail by Einstein and de Sitter (Proc. Nat. Acad. Sci., 18, pp. 213–214, 1932).

Although we have for the sake of simplicity restricted ourselves to a discussion of Friedmann's worlds in which energy is rigorously conserved, the qualitative discussion of types thus found will hold under the much weaker assumption that the energy and the pressure are both positive non-increasing functions of R; a detailed analysis of all such possibilities is included in a comprehensive report on the subject which is to appear soon in Rev. Mod. Physics.

With this we end our survey of the full range of possibilities for a universe in which energy is truly conserved. But allow me to repeat that we should not close our minds to the other cases which may arise. We know, for example, that in at least some portions of the universe (the interior of the stars) there is an active interplay between matter and energy; the matter is being used so as to supply radiant energy. And if Millikan's hypothesis concerning the origin of the cosmic rays proves tenable we must conclude that such an active exchange is yet more wide-spread. The effect of the annihilation of matter on the expansion of the universe has been the starting point of a series of important investigations by Tolman. This same investigator has given us an extension of the principles of thermodynamics which satisfies the fundamental criteria of the general theory of relativity

and has applied it to the question of the thermodynamic relations exhibited by the universes contemplated in relativistic cosmology. He has, for example, thus sought to establish the possibility of a universe in which radiation is in equilibrium with matter and which, although expanding or contracting at a finite rate, does not suffer the ultimate "heat death" which an observer viewing it through the eyes of classical thermodynamics would predict.

Finally, I must call your attention to a doubt which the results outlined above have raised. The time scale which the observed red shift in light from the distant nebulae leads to if interpreted as due to velocity is rather meager. What are we to think of a universe whose radius is at present expanding at such a rate as to double itself every 1,400 million years which contains stars whose age is estimated at millions of millions of years?[3] Perhaps we may be able to conclude that the processes which lead us to these tremendous ages were proceeding at a much greater rate when the world was young, or it may be that the astronomers have been over-zealous in demanding millions of millions of years when but a fraction of that would have sufficed. Einstein and de Sitter appear to have been moved by the rather short time scale to favor a periodic universe in which we are now enjoying the expansion phase, but which may conceivably reverse this tendency before the sun becomes too cold to support life. In addition to those who believe that the at first sight paradoxical time scale is nevertheless reconcilable with the observed facts there exists a group which would attribute the observed red shift, which we have throughout interpreted as a velocity, to a property of light which has traveled the tremendous inter-nebular distances. Zwicky suggested a few years ago that there may exist a mechanism by which the light-corpuscles surrender a minute fraction of their energy to nebulae and other matter which they pass on their journey to us; this loss of energy would be proportional to the distance through which they travel and would, in accordance with our present theory of light, give rise to a red shift in the observed spectrum. In this case our interpretation would be quite false—the observed red shift would be due to the properties of "tired" light rather than to the nebulae themselves. But I do not believe that even if room could be found in our theories for such a modification it would alter essentially the general outlook with which we have been concerned this evening, for so long as we have sufficient evidence in other fields to hold to the general theory of relativity and so long as the homogeneity assumptions with which we started are not at variance with the observations we may consider relativistic cosmology as a simple corollary of the relativity theory. Robbed of all contact with the empirical we would of course be unable to decide which of the alternatives was best suited for a description of the actual universe—perhaps we should fall back on the Einstein universe which was originally offered to us as escape from the paradoxes of an infinite world filled uniformly with matter. But in the lack of further facts I should prefer to wield Occam's razor on all *ad hoc* explanations of the red shift and accept that one which follows so naturally from our present views of the nature of the physical world, the bold outlines of which I have had the pleasure of sketching before you this evening.

[3] I here refer to the attitude which has been expressed by de Sitter (Bull. Astron. Inst. Netherlands 5 No. 193, p. 212, 1930) and which has been adopted by others. I do not consider the objection to be as serious, but do hold it to be a valid argument for a universe of the type $\lambda = \lambda_E$ resulting from a perturbation of the unstable Einstein world.

OBITUARY

CHARLES WILLISON JOHNSON

IT has been said of many great men that kindliness of manner and disinterested helpfulness were among their outstanding traits. Joseph Leidy is remembered by those he taught almost as much for these qualities as for the greatness of his intellect or his innumerable and far-reaching discoveries. Into the early lives of many of us standing awestruck at the threshold of the world of nature, which we wished so much to know better, a hand was stretched out, and a kindly teacher—or better, friend—led our faltering steps through the portal and fixed our life's greatest interest. This brief tribute is to one whose guiding hand placed me on the happy road which teaches boys to see, to understand and to appreciate the world about them.

Charles Willison Johnson was born at Morris Plains, Morris County, New Jersey, on October 26, 1863. Educated in public and private schools at Morristown, New Jersey, he early showed a deep interest in natural history. In 1881, his family removed to St. Augustine, Florida, and there during the succeeding seven years he continued his studies and made extensive collections, chiefly of insects, mollusks and fossils.

In 1888, having been appointed curator of the Museum of the Wagner Free Institute of Science in Philadelphia, he brought to this work a broad knowledge of natural history and an intimate acquaintance with the existing and fossil fauna of Florida. At

the Wagner Institute he proceeded to develop in the museum an excellent local natural history collection and also a detailed synoptic collection of the animal world. At the same time he was able to broaden and increase his interest in the Diptera, so that he soon became one of America's authorities on that group of insects. Recent mollusks also occupied his attention, and these with the Diptera remained his major fields of investigation. For a number of years during his Philadelphia residence he was also actively at work on fossil mollusks, and in charge of the Isaac Lea Collection of Eocene Mollusca at the Academy of Natural Sciences of Philadelphia. In the development of this collection he visited the Eocene deposits of the southern United States a number of times. In 1891, accompanied by William J. Fox, of the Academy of Natural Sciences of Philadelphia, Johnson visited Jamaica, and made extensive collections of the insects and mollusks of that island, his important study of the Diptera of the island being based on these investigations.

With Henry A. Pilsbry in 1890, Johnson assumed the management of the *Nautilus*, associate editor and business manager of which he remained until his death. In 1897 he married Miss Carrie W. Ford, a daughter of John Ford, one of Philadelphia's group of conchologists.

The post of curator of the Boston Society of Natural History being vacant, in 1903 he was appointed to that office, and in the conversion of the Boston Society's museum into a strictly New England one, the succeeding years witnessed the application of his unusual ability to adapt, rearrange and develop museum collections under conditions of limited financial support. This is a rarely met capability, little appreciated by those with lavish funds and many assistants. How much personal labor the years in Philadelphia and the early ones in Boston required is known only to those intimately associated. My personal contact with C. W. Johnson was during most of the Philadelphia period, and it was during these busy years, filled for him with duties of many kinds, that his encouragement of boyish enthusiasm, and the tolerance and patience of our revered teacher and guide, laid the foundations for entomological careers in three of his volunteer youngster helpers.

While on a short collecting trip to his favorite locality, Martha's Vineyard, he was seriously stricken, and died in Boston on July 19, 1932. A fellow of the American Association for the Advancement of Science, Johnson was also a fellow of the American Academy of Arts and Sciences and of the Entomological Society of America, to the presidency of which latter he was elected in 1924. In addition to membership in a number of other scientific organizations, he was a member of the Malacological Society of London and of the Conchological Society of Great Britain and Ireland.

Johnson's studies in the Diptera were productive of numerous original contributions, while his generous aid to fellow students placed at their disposal in special studies the collections secured on his innumerable field trips in the Philadelphia district and in New England. The number of beginners who drew their early encouragement from this born naturalist will never be known, but the memories of his personal magnetism, ever-youthful enthusiasm and kindly help will remain cherished possessions of many now seasoned scientists.

JAMES A. G. REHN
THE ACADEMY OF NATURAL SCIENCES
OF PHILADELPHIA

RECENT DEATHS

DR. OLIVER DIMON KELLOGG, professor of mathematics at Harvard University, died suddenly when climbing a mountain near Greenville, Maine, on August 27. Dr. Kellogg was fifty-four years old.

DR. MOSES ALLEN STARR, professor emeritus of neurology at Columbia University, died on September 4. He was seventy-eight years old.

PROFESSOR EDGAR JAMES SWIFT, head of the department of psychology at Washington University, St. Louis, since 1925, died on August 30, at the age of seventy-two years.

JAMES E. DONAHUE, associate professor of mathematics in the University of Vermont, died suddenly on August 13, at the age of fifty-two years.

DR. NATHANIEL ALLISON, formerly professor of surgery in charge of the division of orthopedic surgery at the University of Chicago, died on August 25, at the age of fifty-six years.

THE death is announced of Dr. Adolf Sauer, professor of mineralogy and geology at the University of Stuttgart; of Dr. Otto Mügge, professor of mineralogy at Göttingen, and of Dr. Albert von Ettingshausen, professor of physics at Graz.

SCIENTIFIC EVENTS

BRITISH VITAL STATISTICS FOR 1930

THE Registrar-General's Statistical Review of England and Wales for 1930, the last of the three volumes for that year, is summarized in the *British Medical Journal*. It contains the official commentary on the vital statistics in Part I Medical Tables and

Part II Civil Tables already issued. There are special sections on deaths, marriages, births, stillbirths, estimated population, vital statistics for Great Britain and Ireland, Legitimacy Act (re-registrations), Adoption of Children Act (registration) and electors (Parliamentary and Local Government). The population at the middle of the year was estimated at 39,806,000 persons. This estimate was largely confirmed by the result of the census in April of the following year, the provisional figure of the census at that later date being 39,947,931. The estimated figure of 39,806,000 was made up of 19,075,000 males and 20,731,000 females. This excess in the number of females is not distributed evenly over the various ages, being most marked in the age groups between 30 and 55. The birth rate was 16.3, thus equalling the rate for the previous year, which was the lowest recorded in this country since the establishment of civil registration. The marriage rate was 15.8 persons married per 1,000 of the population, remaining the same as for the previous year, which was the highest recorded since 1921. The death rate was 11.4, compared with 13.4 for 1929, which had a high rate, owing to the severe weather of the spring period. The rate of 11.4 was the lowest death rate on record. The death rate under 1 year of age was 60 per 1,000 live births, which is the lowest figure recorded, and 5 per 1,000 below the previous record of 65 for 1928. The rate for deaths of mothers from childbirth for 1930 was 4.40 per 1,000 live births against 4.33 for the previous year. The higher figure is owing to a rise in the rate for puerperal sepsis, the figure for "other puerperal causes" showing a slight decrease. It is suggested that this may be associated with the lower birth rate, giving a greater proportion of cases of first-born children, with its consequent slight increase of risk, thus masking any reduction achieved as a result of maternal welfare schemes. The deaths ascribed to cancer during 1930 numbered 57,883 (26,916 males and 30,967 females). These numbers are the highest yet recorded, but when standardized, the rates are 103 for males and 99 for females per 100,000 living, compared with 103 and 100, respectively, for the preceding year. The death rate for diabetes for each sex is slightly lower than in 1929, but, except for 1929, is higher than for several years past. Following on an examination of the figures in the 1924 volume for "crushing by motor vehicles," statistics are given of the differences in 1930, which was the last year before the new Road Traffic Act (1930) came into force. The rate of mortality was more than twice that for 1924, and almost eight times the rate for 1911. Tables which relate to the six years 1925–30 exhibit the increasing mortality especially associated with motor-cycle accidents, and give the number of deaths, with the age groups of the persons, and the types of motor vehicles concerned.

DR. SVEN HEDIN'S EXPEDITION IN CENTRAL ASIA

DR. SVEN HEDIN'S expedition in Central Asia, according to the London *Times*, which quotes from the *Academia*, Berlin, is now working in several separate parties. One section, to which the Swedish explorers, Dr. Nils Ambolt and Dr. Erik Norin, are attached, early this year undertook a journey through northwestern Tibet, hoping to penetrate and chart an entirely unexplored territory. Dr. Norin has now sent to Dr. Sven Hedin in Berlin a wireless message *via* Peshawar as follows:

In April I traveled over the Karatagh Pass and Aksai Chin to the Karakorums. At the beginning of May, according to program, I met Dr. Ambolt and the main convoy. On May 9 I left the convoy again, and with my own separate convoy continued in a northeasterly direction, touching at Camps 15 and 20 established by you in 1907. From your Camp No. 34 we moved into unknown territory and reached Ustuntagh after a difficult trek. In that region I lost my whole convoy, but was able to save the scientific records of our journey. I myself am in good health and all my people are alive.

Dr. Hedin comments on this journey as follows:

I knew that Dr. Norin was planning to reach the Karakorums by way of the Karatagh, and that he had taken a small convoy to Aksai Chin. He and Dr. Ambolt wanted to discover as much unknown land as possible. Evidently the journey through my 1907 camps to the north served the purpose of gaining geological data from the whole Kun-Lun mountain range. It is clear that the convoy was lost in this unknown territory, probably during a very difficult trek. Dr. Norin has lost all his animals, and saved only himself, his porters and his scientific notes. He has asked for support and for his mail to be sent to the Swedish Mission at Kashgar, and seems to have formed new plans for the exact geological examination of Northern Tibet.

A report received by Dr. Sven Hedin from the other expedition working in this region, under Dr. Ambolt, states that he had moved eastwards from Lighten Lake, in Northwest Tibet, in the direction of Termilik, and had crossed and mapped the hitherto unknown Kun-Lun area. Termilik lies south of the Lop-nor, the mysterious lake which the Sven Hedin Expedition of last year revisited. Dr. Ambolt proposes to cross the great belt to the Central Asian Desert. This second expedition is expected to arrive in Peking at the end of November.

THE OAK RIDGE OBSERVATORY OF HARVARD UNIVERSITY

THE cornerstone of Harvard University's Oak Ridge Observatory at Harvard, Massachusetts, where a sixty-one-inch mirror telescope is being constructed, was laid on September 4 by Sir Frank Dyson, astronomer royal of Great Britain and president of the International Astronomical Union. There were present more than two hundred of the world's leading astronomers and their guests.

Forty acres of land have been donated to the college by Alfred Fuller, of the town of Harvard, for the erection of the observatory. The house in which the mirror telescope is being installed will cost $50,000.

The foundation for the new telescope is ready, and the instrument itself will be in operation within two months. When it is completed it will give to Harvard University the fourth largest telescope in the world, being outranked only by the telescopes at Mount Wilson, California, Victoria, British Columbia, and Delaware, Ohio.

Professor Howard Shapley, director of the Harvard College Observatory, in placing a copper box in a recess, stated that this was done to enlighten astronomers five centuries from now as to how far advanced the present-day astronomer is. He said:

> We have placed in this box twenty astronomical journals in fifteen different languages, the signatures of seventy-nine members of the Harvard Observatory, a program of the 1932 meeting of the International Astronomical Union and a photograph of the International Astronomical Union at dinner last night.

Sir Frank Dyson spoke as follows:

> In laying the cornerstone, I feel like a godfather who has been asked to look after the welfare of a child. And as is the custom of godfathers I place the caring of this magnificent observatory into the hands of its most capable parents. It will now make it possible for Harvard Observatory to photograph the stars and heavens in both hemispheres and give them a thorough knowledge of the general structure of the "Milky Way."

After the dedication ceremonies Professor Shapley explained that the telescope will be used for study of the sky in the northern hemisphere and that the Harvard Kopje observatory in Bloemfontein, South Africa, which has a sixty-inch mirror telescope, is to be used in the study of the southern hemisphere.

THE FIRST ELECTRIC LIGHTING PLANT

THE fiftieth anniversary of the opening by Thomas A. Edison of the first commercial electric lighting and generating plant in the world at 257 Pearl Street, New York City, was commemorated on the afternoon of September 4 with simple ceremonies on the site of the original plant. The whirring of the original dynamo was heard several hundred miles away from the Ford Museum at Dearborn, Michigan, relayed by radio and amplified through loud speakers.

In the broadcast from Dearborn, before the start of "Old Jumbo No. 9," the following telegram from President Hoover, in Washington, was read:

> Mrs. Hoover and I regret that we can not be with you, but are glad to have the opportunity of joining in your tribute to the genius of Thomas A. Edison on this anniversary. The debt which this country, and indeed the whole world, owes to Mr. Edison is everywhere recognized, but in this universal acclaim let us not forget the fine and admirable character, the lofty soul, of the man to whom we owe so much. Here also is a source of pride to all Americans.

One of the speakers was Charles Edison, son of the inventor. A message from Mrs. Thomas A. Edison was read. Also present were Thomas A. Edison, Jr., and W. W. Nichols, vice-president of the Allis-Chalmers Company, brother-in-law of the inventor. About 100 persons, including many leaders in the electric lighting industry, attended the ceremonies.

Besides Mr. Edison the speakers were Frank W. Smith, president of the New York Edison Company, and H. A. Campbell, who went to work for Edison in 1878, nearly a year before the perfection of the incandescent lamp, and who had charge of the construction of the first station. Mr. Campbell, now seventy-nine years old, is still in active employ of the Edison Company, being in charge of one of the three sub-station districts in Manhattan.

A further celebration will be on September 12, at a dinner to be attended by representatives of civic, scientific and engineering bodies.

THE CORNELL MEDICAL CENTER

THE new buildings of the Cornell Medical Center, erected at a cost of thirty million dollars, were declared open on September 1, when a tour of inspection, headed by Dr. G. Canby Robinson, director of the joint administrative board, took place. The buildings are situated in York Avenue between Sixty-eighth and Seventy-first Streets overlooking the East River.

Under the official name of the New York Hospital-Cornell Medical College Association the new institution provides 1,007 beds, a medical center of twenty-six operating rooms and 264 laboratories. It combines the facilities of the New York Hospital, oldest in the city and second oldest in the United States; the Lying-in Hospital, the Manhattan Maternity and Dispensary Hospital and the Medical College on one

site with divisions designated as the general hospital, the women's and children's hospital and the psychiatric hospital.

The center is composed of a group of eleven connected buildings, rising in its highest part twenty-seven stories and covering six and a quarter acres. The interior floor space of forty-five acres is traversed by five miles of corridors.

Above the administrative offices on the first floor of the central building are, in order, eight floors of wards, two of operating rooms and five of rooms for private patients, with the remainder given over to staff quarters.

The largest of the wards accommodate sixteen beds. They are designed after those in the Royal Hospital at Copenhagen and represent a virtually new departure in this country. The hospital is provided with glass partitions between beds, the most modern type of diffused lighting, adjoining solaria and bedside connections to a central electrocardiograph, the most advanced type of pneumatic communication system, air filtering and humidifying devices and ventilators.

On Seventieth Street to the north is a home for 500 nurses, the power plant, the laundry, shops, quarters for servants and employees and a garage for 250 cars.

The New York Hospital, which has now vacated its old home in West Sixteenth Street, was founded in 1771. A bequest to that institution of $18,632,176 by the late Payne Whitney, who died in 1927, was largely responsible for the new center, which had been sponsored by Mr. Whitney. Other large contributions were those of $2,000,000 each from J. P. Morgan, the Laura Spelman Rockefeller Memorial and jointly from the late George F. Baker and his son.

SCIENTIFIC NOTES AND NEWS

THE one hundredth anniversary of the birth of Wilhelm Wundt will be celebrated in the Leipzig laboratory of psychology in October. Professor Wundt was born in Baden on August 16, 1832. He became professor of philosophy at Leipzig in 1875 and founded in 1879 the first psychological laboratory.

DR. IVAN PAVLOV, professor of physiology at Leningrad, who celebrates his eighty-third birthday on September 14, presented papers at the International Congress of Psychology recently held at Copenhagen and at the International Congress of Physiology recently held at Rome.

DR. ROBERT A. MILLIKAN, of the California Institute of Technology, left Pasadena on September 1 for an expedition to conduct measurements on the cosmic rays as close to the north magnetic pole as transportation facilities permit. The Royal Canadian Air Corps will furnish planes. It is expected that later Dr. Millikan will continue his work south through the United States as far as Texas.

DR. ARTHUR H. COMPTON, of the University of Chicago, has been making measurements on the cosmic rays 100 miles north from the Arctic circle and 350 miles from the magnetic pole. Dr. Compton expects to return to Fort Churchill, Manitoba, on September 10 or 12.

DR. HERMAN SCHNEIDER, who recently resigned from the presidency of the University of Cincinnati, has been awarded a prize of $500 for "outstanding achievement in education" by the Cincinnati Institute of Fine Arts. Dr. Schneider was dean of the college of engineering of the university.

THE title of professor emeritus has been conferred on Dr. Robert MacDougall on his retirement from the chair of analytical psychology at New York University, which he has held for thirty-one years.

DR. OTTO HÖLDER, professor of mathematics at Leipzig, celebrated the fiftieth anniversary of his doctorate on August 3.

THE freedom of the city of Vienna has been conferred on Dr. Hans Horst Meyer, formerly professor of pharmacology in the university.

THE municipal council of Rouen has decided to call one of its streets after Dr. Charles Nicolle, a native of the city, who was recently appointed professor of medicine at the Collège de France.

THE University of St. Andrews has conferred the doctorate of laws on Sir James G. Frazer, author of "The Golden Bough," and on Dr. L. R. Sutherland, emeritus professor of pathology in the university.

ROBERT W. MORRISON, of the University of Tennessee, has been elected associate professor of pharmacology at the University of South Carolina.

PROFESSOR ALEXANDER GALLOWAY, of the department of anatomy, University of Saskatchewan School of Medicine, Saskatoon, has been appointed professor of anatomy at the University of Witwatersrand, Johannesburg, South Africa.

THE following appointments to University of London readerships are reported in *Nature:* Experimental pathology, Lister Institute of Preventive Medicine, Dr. E. W. Hurst, formerly pathologist to the Millbank Research Fund at the Lister Institute; mathematics, Imperial College—Royal College of Science, Dr. W. H. McCrea, lecturer in mathematics in the University of Edinburgh; pathological chemistry, the

Cancer Hospital, Dr. J. W. Cook, research chemist in the Research Institute of the Cancer Hospital.

AT a meeting of the board of the British National Institute for Research in Dairying, Reading, Professor H. D. Kay was appointed director of the institute in succession to the late Professor Stenhouse Williams. Dr. Kay, who is resigning the professorship of biochemistry in the University of Toronto in order to take up the appointment at Reading, has been engaged in research work in biochemistry at various times in the Universities of Cambridge, London, Manchester and Toronto.

THE British Medical Research Council has appointed Ernest Bevin, Dr. C. G. Douglas and W. S. Morrison, M.P., to be members of the Industrial Health Research Board in succession to Arthur Pugh, Professor E. P. Cathcart and Major A. G. Church, who retire on September 30.

T. R. READ, assistant director of extension at the University of Arkansas, was elected president of the Southwest Soil and Water Conservation Conference which was recently held at the university.

WILLIAM W. WINSHIP was recently elected chairman of the New York section of the Electrochemical Society.

CURTIS P. CLAUSEN, of the Bureau of Entomology, who has been in charge of research work on parasites of the citrus black fly at Kuala Lumpur, Federated Malay States, recently was transferred from the field to the departmental service. In the new assignment he is coordinating the work of the divisions of the bureau and of cooperating states concerned with the importation and use of beneficial insects.

DR. FRED SOPER, director of the campaign of the Rockefeller Foundation for the eradication of hookworm in Paraguay, will cooperate under the auspices of the foundation with the Argentine government in efforts to bar from Argentine territory the yellow fever epidemic in the Santa Cruz district of Bolivia.

DR. ALBERT ANDRÉ will leave New York for Tibet in the autumn with six scientific assistants. He proposes to chart the course of the Brahmaputra River through the Great Gorges of the Himalayas.

DR. F. SASS, chief engineer for the German General Electric Company, an authority on Diesel engines, is now visiting the United States.

DR. EARLE R. HEDRICK, professor of mathematics and chairman of the department of mathematics at the University of California at Los Angeles, has returned to Los Angeles following the completion of a survey of mathematics in the colleges and universities of the North Central States. Dr. Hedrick was chairman of a committee appointed to complete a survey and report the findings of approximately four hundred schools of higher education comprising the North Central Association. The field of this committee was confined to a study of mathematics as a specimen subject and extended to a survey of materials used, and the teaching of mathematics in the schools of the association.

THE British Medical Research Council announces that, on behalf of the Rockefeller Foundation it has made the following awards of traveling fellowships for the academic year 1932–33: Colin Panton Beattie, bacteriology department, Edinburgh University; William Donald Wykeham Brooks, St. Mary's Hospital, London; Eleanor Mildred Creak, Maudsley Hospital, London; Ian George Wilson Hill, Royal Infirmary, Edinburgh; William Arthur Mackey, department of surgery, Glasgow University; David James MacMyn, King's College Hospital, London; John Chassar Moir, University College Hospital, London; Dr. Brooks and Mr. MacMyn have been appointed on modified conditions while receiving emoluments from other sources. These fellowships are awarded to graduates who have had some training in research work either in the primary sciences of medicine or in clinical medicine or surgery, and who are likely to profit by a period of work at a chosen center in America or, in special cases, in Europe, before taking up positions for higher teaching or research in the British Isles.

WE learn from *The Geographical Journal*, London, that at the instance of the Secretary of State for the Colonies the Royal Geographical Society has arranged to house the specimen cadastral survey, land registry and land revenue records which were exhibited at the Science Museum last July upon the occasion of the second Conference of Empire Surveyors. This is in execution of the wish expressed by the conference that the exhibits should be retained in some appropriate center in London, as the nucleus of a permanent collection for reference and study. With this object in view it is hoped gradually to supplement the original exhibits and build up a really comprehensive and representative collection gathered from all parts of the world and exemplifying work of this nature carried out under all sorts of conditions and to meet all sorts of needs. It is intended that the collection shall include land laws, regulations and technical instructions, and that as it grows it shall also be kept representative of, and abreast with, progressive advances in cadastral survey and land records in each country. No funds are available for the purpose, and so success in attaining the objects arrived at must depend

upon the systematic cooperation of the survey and land services everywhere, coupled with the very valuable help that those who have been personally concerned with the conduct of such work in various parts of the world may be able and willing to give. Sir Ernest Dowson and Mr. V. L. O. Sheppard have jointly undertaken the collection, study and maintenance of the documents. As soon as the millboard covers that are needed to preserve them have been supplied the specimen maps and records will be available for consultation at any time during the society's working hours upon application in the Map Room. But Sir Ernest Dowson and Mr. Sheppard will only be able to visit the Society's House fortnightly or by special arrangement, and will do most of the necessary work in their own homes. Those interested, or in a position to assist, are accordingly requested to communicate with them at their private addresses, which are respectively: Bowyers Field, Wrotham, Kent, and Gordon Lodge, Kemble, near Cirencester, Gloucestershire. Rolls of maps or other bulky parcels should however be sent to them to the care of the society.

Nature states that the Royal Society has issued in one alphabet an author index to its *Proceedings,* Series A and B, from 1905 to 1930, and to the *Philosophical Transactions,* Series A and B, from 1901 to the same year, the entries being arranged chronologically under each heading. A previous index to the *Proceedings* was published in 1913, which covered the period from 1800 (when the series began under the title "Abstracts of Papers printed in the Philosophical Transactions") to the year 1904, so that the author index to this publication is now complete to the year 1930. The only indexes to the *Philosophical Transactions* hitherto available have been author and subject indexes down to the year 1830, but the "Catalogue of Scientific Papers," which includes papers in the *Philosophical Transactions,* may be considered to continue the indexing under authors' names down to the year 1900, whence the new volume completes it to the year 1930. So far as the author index is concerned, therefore, the indexing of the two publications is available for their entire runs. A subject index from 1800 is still lacking, except in so far as the mathematical, mechanical and physical papers for the period 1800–1900 are concerned, since these have been included in the three published subject indexes to the "Catalogue of Scientific Papers," which covers both publications.

IT was planned to bring the question of industrial standardization before the recent Imperial Conference held in Ottawa. C. le Maistre, director of the British Standards Institution, had been appointed adviser to the delegation from Great Britain on British standards. At the last two Imperial Conferences, according to *Nature,* great importance was attached to the development of inter-Empire standardization, and to the preparation of national industrial specifications by national standardizing bodies. In order to fulfill the recommendation of the last Imperial Conference, the British Engineering Standards Association recently widened its scope, and is now known as the British Standards Institution. Since last November, le Maistre has been touring the Dominions in connection with the development of this work.

OWING to the world-wide depression, according to a correspondent of the *Journal* of the American Medical Association, the offer to Japan from the Rockefeller Foundation to the School of Hygiene and Public Health to be built in the near future has been postponed until better economic conditions return. But the candidates for membership who are in America it is believed will continue their studies. The establishment of the school, it is now hoped, will go ahead with funds from the state independently of the receipt of funds from the Rockefeller Foundation.

ACCORDING to the *Journal* of the American Medical Association, a survey to determine the adequacy of facilities and the extent to which provisions are made for the protection of the public health in the care and treatment of leprous persons in Hawaii has been authorized by a joint resolution of Congress. The resolution was based on information furnished by the governor of Hawaii to the effect that there are at the present time 623 patients being cared for at the expense of the territory in its leprosariums. The cost entailed in this care is considered a heavy burden on the "limited resources of the territory." Physicians of the U. S. Public Health Service who will conduct the survey are: Drs. James C. Perry, John W. Kerr and George W. McCoy. They will prepare an estimate of the cost of construction and equipment of a receiving station and hospital, including the purchase of necessary grounds as well as an estimate of the annual cost of maintenance and operation. They will also report on remedial legislation providing for the further control and eradication of the disease in the territory. In 1905, a congressional appropriation provided for the establishment of a hospital station and laboratory of the Public Health and Marine Hospital Service of the United States for the study of the methods of transmission, cause and treatment of leprosy at Kalawao, Island of Molokai. About 640 acres was transferred in perpetuity to the United States by the territory. However, after several years' operation, it was found impracticable for the United States to maintain a separate institution, and through subsequent legislation the land was reconveyed to the territory. Except for a station at Kalihi receiving

hospital, Honolulu, the territory has since then borne the complete expense of caring for leprous persons in its jurisdiction. None of the territory leper patients have been cared for in the leper colony at Carville, La., the establishment of which was provided for by an act of Congress in 1917. The Kalihi station, known as the U. S. Leprosy Investigation Station, is administered by the Public Health Service.

DISCUSSION

SHOULD SCIENTIFIC DISCOVERIES BE PATENTED?

IT is becoming increasingly common for investigators in various fields to apply for patents on materials, processes or apparatus which have resulted from their work. Certainly in most cases this has been done without any desire to obtain personal reward from the sale of patent rights or the income from royalties. Within the last few years there have been established impersonal organizations to hold these patents, such as the Insulin Committee at the University of Toronto and the Wisconsin Alumni Research Foundation. The benefits from such legal control of discoveries have been made available to many investigators in the institutions where such organized control has been provided.

When informal groups of men gather at the various conventions of American scientific investigators, the advisability of the patent method of control is being debated with considerable frequency. Although this is not unusual, it is unfortunate that emotional reactions are beginning to appear in this discussion, and there is present the material out of which serious jealousies are almost certain to appear. No discovery in science is made by an individual unaided by the enormous background of science in general. Consequently, it is debatable whether one man should have credit for the climax of a long series of studies which come to recognized fruition in his hands. The nearly simultaneous discoveries of the same fact are only too frequently disappointing for one of those involved. Just apportionment of credit will remain difficult. Patents may serve to give legal intrenchment to rights which are not permanently and justly tenable. The feelings of many men who are engaged in scientific research are beginning to be aroused on these questions. It is to be hoped that they will not be allowed to reach a point where there is any spoiling of the fine camaraderie which has characterized American laboratories and science meetings.

If an attitude of suspicion and jealousy should develop in this country between the scientific men of our numerous institutions, it would be very apt to lead to the throwing of a cloak of secrecy about all work of interest. It is obvious that this would hamper progress in research and in teaching, as well as in practical applications of science. Certainly no one desires such an outcome of the rivalry in investigation, which is now for the most part a good-natured and open race. When patents are commonly resorted to, both those who do apply for them and those who prefer not to will feel that secrecy is necessary.

Of course there are advantages to the use of the patent. The public is thereby protected against certain ruinous types of exploitation. Assurance can be gained that technical processes are used in dependable ways. Even the publicity may be kept on a satisfactorily high plane. Rapid development of discoveries which are of academic interest may be secured when patent rights assure a commercial producer of protection in the field. And further, the income from the sale may be made to yield to the scientific laboratories that wherewithal for more work which is always a concern of the administrative officers. The financial support of research may become thereby an increasingly secure endowment, growing by geometrical progression.

On the other hand, an example of the danger of grave disadvantages is contained in the possibility that a patent for a "discovery" in such a shifting field as that of internal secretions may be granted when no real advance has been made, but that this patent will serve to place very unfortunate strictures on other men who subsequently do fundamentally important work in the same field. This could well delay the availability in practical medicine of some of the dramatic discoveries of recent years. Patents may be abused as well as be made to protect the interest of the public.

These obvious suggestions are made not to offer an answer to this vexing question, but to stimulate a more public debate on the merits of patenting discoveries. Might not the American Association for the Advancement of Science have a formal presentation of this matter at its next meeting? Perhaps two proponents of the patent scheme might have each a twenty-minute opportunity to present the advantages, with two others opposed to this method using a similar time for the contrary point of view. This could be done with dignity and with freedom from personal bias or emotional twist. The matter is of general importance, justifying the attention of all men in science. The printing of such a discussion would undoubtedly develop further ideas from the minds of the readers of SCIENCE. It might be worth while

to have the manuscripts for such a debate prepared far enough in advance so that all the speakers would have opportunity to read them before they were delivered. The questions at stake could thereby be brought actually to concrete discussion with less waste of time or failure to meet issues.

A further scheme for control might serve to solve many of the difficulties suggested above. Might not the control of all practical exploitation of discovery be vested in one authoritative body for the nation? Whether it be by patent or by the sanction of widespread agreement, no manufacturer would be allowed to sell a drug unless its production and sale were according to definite ethical standards. Income from such sales could be used to provide a royalty for the research funds to support investigation in whatever laboratories needed assistance. This concept would be extended to any phase of scientific work desired. The creation of a single controlling body for the country would do much to remove the danger of jealousies between institutions. The opportunity would be open for all laboratories to profit from discovery in general, as a fair return for the admitted fact that every discovery is based on the previous work of countless investigators. Control of the product of our research would be accomplished with as broad a social vision as such a central organization could furnish. The commercial interests could be adequately protected at the same time.

It may be mentioned that the American Medical Association has made a beginning of a non-legal control of drugs and foods involving part of this social protection. Perhaps the National Research Council might be made the holder of all such patents or the central body to control the application of research in commercial production. The council has already developed a wide acquaintance with the needs of American laboratories. It has provided opportunities for many students to continue investigation. Its limited funds have been dispensed by a changing group of men from the ranks of scientists themselves. The council has earned the respect of the investigators of the country. In this organization, already set up, may be the basis for an unselfish authority to advance research and its prompt application in the life of men even more effectively.

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POTASSIUM PERMANGANATE AS AN ANTIDOTE FOR SNAKE VENOM

FOR many years one of the most generally recommended antidotes for snake poison has been potassium permanganate. More recently, considerable doubt has been expressed as to the efficacy of this chemical in cases of snake-bite.

At intervals for the past two years the writer has been experimenting with white rats in the endeavor to get some experimental evidence upon the subject. An abundant supply of dried venom of rattlesnake was obtained through the courtesy of the Antivenin Institute of America. This dried venom dissolves readily in normal salt solution and may thus be injected into the animal with an ordinary hypodermic syringe. Subcutaneous injections were made, owing to the difficulty of injecting directly into a blood vessel in so small an animal; this requires a larger quantity of venom for each animal, but the effect is quite promptly evident, death in some cases occurring within an hour and generally, if it occur at all, within twenty-four hours.

The animals were etherized for ease of manipulation, and the permanganate in the form of a 1 per cent. solution in distilled water was injected immediately after the venom and at the same spot.

The rats were found to be, relative to their size, highly resistant to the Crotalus venom; and within a comparatively wide range the size of the rat had little relation to the amount of venom necessary to produce death.

Two hundred and sixty-seven rats were used, but in the endeavor to find a minimum lethal dose of the venom many were killed without gaining any direct information upon the main object of the research. More than a dozen were used to prove that injection of the permanganate solution alone is not nearly so harmful to living tissues as has been claimed. There was so much variation in the individual susceptibility of the rats to the venom that it seemed impossible to determine a minimum lethal dose, and after many trials it was found that 20 milligrams of the dried venom was about the smallest amount that could be called a "certain lethal" dose, and in some cases this failed to be lethal. About half of the rats were injected with the venom alone, and in the other half the venom was immediately followed by an injection of the permanganate.

In the chief experiment, where the rats were given 20 mg of venom, the results seemed to show a distinct value for the permanganate. Of 48 rats given the venom without the permanganate only 7 rats, or 14.6 per cent., recovered; while in the 47 rats in which the permanganate followed the venom 13 rats, or 27.7 per cent., recovered. Also the average number of hours that the rats which died survived was 21.3 in the case of the rats without the permanganate and 31.3 in rats which had received the permanganate; in

other words, the permanganate delayed death for ten hours, on the average.

Some of the other experiments, with greater or less amounts of venom, gave opposite results and seemed to indicate that the permanganate has little if any value.

A tabulation of all the experiments indicates that a prompt use of the potassium permanganate had some beneficial effect under the conditions of this investigation. Whether it necessarily indicates its usefulness in cases of human snake-bite accidents, it is difficult to say; but since it seems evident that a 1 per cent. solution of potassium permanganate is practically harmless to living tissues, it is probable that the permanganate should still be used as an antidote to snake venom, at least as a first-aid treatment until other measures can be taken.

The value of incision and suction in the region of the bite is also subject to much debate, but the evidence seems to indicate that prompt and continuous mechanical suction may be of great value in removing the venom from the tissues in the region of the wound.

A more valuable series of experiments might be made with some larger animal where direct injection of venom and permanganate might easily be made into the blood vessels. Some authorities, however, claim that where the snake injects the venom directly into a blood vessel of some size nothing can be done that will effect a cure.

It is obviously not practicable to carry on such control experiments with human beings, but an extensive statistical study of cases of human snake-bite, where permanganate and other remedies are and are not used, should be of great value. India, where more than 20,000 people die each year from snake-bite, would probably be the best region in which to make such a study.

The details of this investigation will appear elsewhere.

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UNDERGROUND WATER AS A TRANSPORTING AGENT FOR GASOLINE

ON May 30, 1930, shortly after the opening of a filling station in Wooster, Ohio, gasoline was discovered floating on the surface of the water in a dug well, located 447 feet from the station. On the same day, a five-gallon can was filled with gasoline obtained from the well. On July 18, 1930, 65 gallons were drawn off. At a later time 45 gallons were removed and large quantities drawn off from time to time, until about November, 1930, when the accumulation decreased at a constantly diminishing rate. At no time since the discovery of gasoline in the well has the water been free from the odor of gasoline or the liquid itself. A constantly flowing spring in line with the dug well, and 622 feet from the gasoline station, was polluted; gasoline accumulated in a thick layer on the surface, the excess flowing into a creek, the water of which was rendered unfit for drinking by live stock. Across the road, 141 feet from the station, and in line with the well, a hole was dug to a depth of 12 feet. Gasoline was discovered floating on the water which appeared at the bottom of the excavation. Workmen who were digging a trench on the road between the station and the dug hole reported heavy gasoline fumes at a point opposite the station.

The station, well and spring are located on a slope, the former standing at a higher elevation. The ground water is therefore moving from the station toward the well and spring. Gasoline issuing from holes in defective tanks at the station makes its way downward through the bed-rock until it reaches the ground water upon which it floats. The bed-rock is thin-bedded and well-jointed sandstone, through which the underground water can easily move. The gasoline is transported down-slope by the water, spreading out fan-like, finally reaching the well and spring. Several gallons of brightly colored kerosene were placed in the dug hole opposite the station. In 23 hours the colored material appeared in the well; the underground water had moved a distance of 306 feet in that time.

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MYOESTHESIS AND "IMAGELESS THOUGHT"

IN the course of an experimental test of the behavioristic theory of thinking there was occasion for artificially inducing minimal or "implicit" contractions of human muscles by electrical stimulation. This work yielded a result which is of interest in connection with the "imageless thought" controversy, in that it sheds further light on the non-sensorial and imageless experiences reported by Binet, the Würzburg workers and Woodworth.

To very feeble electrical stimuli our subjects responded with a "sensation of electric shock" but no perception of movement. As the stimulus intensity was progressively increased, muscular contractions were elicited which were objectively recordable and even visible to the naked eye, yet not perceptible kinesthetically by the blindfolded subjects. It was not until the movements were fairly large in amplitude that the subjects reported kinesthetic awareness of them. This result was consistent and was found to hold for both faradic and galvanic stimulation, and for both trained and untrained subjects. The implication is that the supposedly non-sensorial or "pure

thought" experiences of the Würzburgers may appear as such in consciousness simply because of the limitations of introspective observation, and that muscular activity might actually be present all the while without being introspectively detectable.

The foregoing applies only to muscular factors in thinking, and not to imaginal data of other sensory modalities. While the writer's electromyographic records tend to show that the traditional kinesthetic image is really a proprioceptive awareness of existing muscular contraction, they do not as yet yield a decisive answer to the question of whether all modalities of imagery are fundamentally muscular in nature: If the latter hypothesis (first propounded by Dunlap in 1907) should be proved valid, the present result concerning the comparatively high threshold of myoesthetic sensibility would serve to explain "imageless thought" in its entirety.

This finding also provides a simple physiological answer to an objection raised against the peripheral or motor theories of thinking;—the objection, namely, that if the motor theory is valid, the thinker should experience a kinesthetic awareness of the peripheral muscle-contractions, whereas actually such awareness is frequently lacking. Dunlap meets this objection by stating that the muscle-patterns, like those of the ocular muscles in depth-perception, act merely as unperceived "signs" whose meanings alone enter into consciousness. Rexroad has subsequently offered a somewhat similar explanation. In the light of our experimental results, however, a less involved explanation would be that such muscle-patterns remain unperceived simply because they are below the threshold-intensity for myoesthesis.

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SCIENTIFIC APPARATUS AND LABORATORY METHODS

PRESERVATION OF BACTERIAL CULTURES UNDER LIQUID PARAFFIN

NUMEROUS attempts have been made to obviate frequent and essential transfers of bacterial cultures in order to keep stock strains alive. Swift[1] was able to keep alive certain strains of *Meningococcus* for several months by freezing and drying the cultures at low pressure. Hiss[2] kept several strains of *Meningococcus* alive for as long as 14 months in a medium consisting of 1 per cent. glucose broth and 1 per cent. calcium carbonate. Murray[3] succeeded in keeping meningococcic cultures alive for 6 months to 1 year on Dorset's egg medium and the tubes sealed with cotton plugs soaked in molten wax. Other investigators have been less successful with this method. Bruni[4] made the important observation that strains of *Meningococcus* grown on ordinary agar could be kept alive after 80 days at 37° C. if layered with liquid paraffin. Parish[5] confirmed Bruni's observation and extended the study to include besides the *Meningococcus* several strains of *Gonococcus, B. influenzae* and *M. catarrhalis*. These cultures he cultivated on ordinary agar, blood agar and trypagar for 24 to 48 hours at 37° C. when he added approximately 8 cc of previously sterilized liquid paraffin to each tube and replaced the cultures in the incubator. In this manner he succeeded in keeping *Meningococcus* and *B. influenzae* alive for 8 to 12 weeks, *Gonococcus* and *M. catarrhalis* for 16 to 22 weeks. Control cultures in tubes sealed with cotton plugs soaked in molten wax usually died in 2 to 3 weeks.

We have repeated Bruni's and Parish's studies with 2 strains of each of the following organisms: *Streptococcus hemolyticus* (scarlet fever and erysipelas), *Streptococcus viridans, Pneumococcus,* types I, II, III and IV, *Gonococcus, Meningococcus, B. influenzae, B. pertussis* and *C. diphtheriae* (Park 8 A). The bacteria were grown on blood agar slants for 24 to 48 hours at 37° C., when approximately 10 cc of sterile liquid paraffin were added to each tube from a pipette. At this time rubber stoppers were substituted for cotton plugs and the cultures replaced in the incubator. It was apparent that bacterial metabolism was slowed down by the addition of liquid paraffin and that no appreciable increase in size of colonies took place during the subsequent long periods of incubation. It was also noted that the blood agar discolored exceedingly slowly under liquid paraffin, in contrast with the rapid development of chocolate color in the control culture tubes within 2 to 3 days at 37° C.

Subcultures were made onto blood agar plates by removing a small platinum loopful of surface growth, at bi-weekly intervals. Care was taken to allow the liquid paraffin to run off the loop by touching the wire against the sides of the tube. *Meningococcus, Gonococcus* and *B. influenzae* were found to remain viable for 10 to 12 weeks under liquid paraffin. *Pneumococcus,* type III, lived for 16 weeks. *Strepto-*

[1] H. F. Swift, *Jour. Exp. Med.*, 1921, xxxiii, 69.
[2] P. H. Hiss, Zinsser's "Textbook of Bacteriology," 6th edition, p. 436. 1927.
[3] E. G. D. Murray, *System Bact. Med. Res. Coun.*, London, 1929, ii, 291.
[4] E. Bruni, *Ann. di. Med. nav. e. col.*, 1930, xxxvi, ii, 396.
[5] H. J. Parish, *Jour. Path. and Bact.*, 1932, xxxv, 143.

coccus hemolyticus, Streptococcus viridans, Pneumococcus types I, II and IV, *B. pertussis* and *C. diphtheriae* remained viable after 24 weeks under liquid paraffin. Control culture tubes sealed with rubber stoppers were dead within 1 to 4 weeks at 37° C.

The morphological structure of organisms and colonies, as well as the biochemical and serological reactions remained essentially unchanged throughout the entire period of survival. Virulence of all the 4 types of *Pneumococcus* were greatly reduced. Toxigenicity and virulence of *C. diphtheriae* were not greatly altered after 24 weeks' subculturing under liquid paraffin, and pellicle-formation remained the same as before the incubation under liquid paraffin. Hemolytic and toxigenic principles of the *Streptococcus hemolyticus* isolated from erysipelas and scarlet fever sources were not appreciably altered by this method of preserving the cultures.

Viability of bacterial cultures for many months under liquid paraffin at 37° C. doubtless is due to prevention of drying as well as protection against the harmful action on bacteria of oxygen, which Phelon, Duthie and McLeod[6] showed lead to the early death of organisms by the rapid development of alkalinity in the medium. This simple method of keeping delicate bacteria alive for months is exceedingly practicable and labor-saving in laboratories entrusted with large stock culture collections.

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THE CULTIVATION OF NYCTOTHERUS OVALIS AND ENDAMOEBA BLATTAE

Nyctotherus ovalis from the hindgut of the cockroach, *Blatella germanica,* can be easily cultured in a modified Smith and Barret[1] medium. This medium was used by the discoverers for *Endamoeba* (*Entamoeba*) *thomsoni,* and according to Lucas[2] it is suitable for the cultivation of neither *Endamoeba blattae* nor *N. ovalis.* The medium as used by Smith and Barret[1] consists of 19 parts of 0.5 per cent. NaCl to one part of inactivated human blood serum. By substituting non-inactivated rabbit serum for the human serum a medium is produced in which *N. ovalis* lives and multiplies freely. Dividing forms are common, and occasionally precystic and cystic forms are met with. Three cultures have been maintained for 40 days and at the last examination the organisms were as normal in appearance as those found in their native habitat. Subculturing is done at weekly intervals, and the cultures are maintained at room temperature.

The cultivation of *E. blattae* has been less successful than *N. ovalis.* Two cultures out of 12 attempts were maintained for 29 days. At the end of this time the organisms were few in number, but entirely normal in appearance and movement. One 2- and one 8-nucleate form were seen, the latter with nuclei of different sizes and evidently precystic. The next examination was negative. This gradual dwindling in number does not necessarily indicate an unfavorable environment, but rather that division is not frequent enough to permit weekly subculturing, without gradually diminishing the number of organisms to the point of extinction. Longer intervals between subcultures result in an overgrowth of bacteria and the small flagellate *Monocercomonas orthopterorum.*

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[6] H. V. Phelon, G. M. Duthie, and J. W. McLeod, *Jour. Path. and Bact.,* 1927, xxx, 133.

[1] N. M. Smith and H. P. Barret, "The Cultivation of a Parasitic Amoeba from the Cockroach," *Jour. Parasit.,* 14: 161–175, 1928.

[2] C. L. T. Lucas, "A Study of Excystation in *Nyctotherus ovalis* with notes on other Intestinal Protozoa of the Cockroach," *ibid.,* 14: 272–273, 1928.

SOME NOTES ON EMBRYOLOGICAL TECHNIQUE[1]

IN the course of some varied experiences with the sectioning of a wide variety of vertebrate eggs and embryos I have worked out a few tricks of technique that have been of value in handling difficult material. I am offering these in the hope that they may be of use to other embryologists. The two points which have been of most importance in getting good results are fixation and dehydration, and I shall take up each of these briefly.

FIXATION

Bouin's has proved to be the best fixative for general use on vertebrate material. Except for certain special purposes, such as the study of lipoids, I have found no fixative to compare with it in its faithful preservation of cellular relations without shrinkage or distortion. The length of fixation must, however, be carefully regulated according to the animal, for what is satisfactory for one is entirely wrong for another. In general, delicate tissues should be fixed a lesser time. For example, mammalian blastocysts fix in thirty minutes to an hour; chick embryos of three days or less in an hour; 10 mm pigs in two hours or more. There are other differences, however, which are absolutely unpredictable. Armadillo embryos and ovaries may be stored in Bouin's for days or weeks without injury; carnivore or rodent material will not stain properly if fixed more than about four hours. The optimum time must be determined

[1] Contribution number 231 from the Zoological Laboratories of Indiana University.

for each form, although there are some, like the armadillo, which give equally good results after almost any period of fixation.

In some forms which have yolky eggs, fixation tends to harden the yolk until it is almost impossible to section satisfactorily. In such cases dilution of the fixative with an equal amount of water may give satisfactory results. This procedure has proved successful with fish eggs and reptile eggs, after ordinary methods had failed completely, and it gives more consistent results with amphibian ova than does the full strength fixative. Mitotic figures in embryos are as distinct and well-fixed following the dilute Bouin's as they are when preserved in the full-strength fluid.

DEHYDRATION

Even after proper fixation, it may prove difficult to get good sections. Many difficulties have been blamed upon the hardening effects of xylol and the paraffin oven. I have come to realize that neither xylol nor paraffin of any reasonable temperature can do any damage comparable to that caused by alcohols of 80 per cent. or higher. To avoid the use of these alcohols I substitute anilin oil as a dehydrating agent. The procedure used is as follows.

Material fixed in Bouin's—35 per cent. alcohol—50 per cent. until excess picric acid is removed—$\frac{1}{3}$ anilin + $\frac{2}{3}$ 70 per cent.—$\frac{2}{3}$ anilin + $\frac{1}{3}$ 95 per cent.—pure anilin until tissue is completely cleared—$\frac{1}{2}$ anilin + $\frac{1}{2}$ xylol (or use more gradual steps if material shows tendency to shrinkage)—xylol at least an hour—xylol + paraffin—paraffin.

I have left material, treated in this way, over night in xylol, and in a paraffin oven for twelve hours at 58°, without making it brittle or hard. The same material, run through absolute alcohol, would have shattered to pieces or turned the edge of the microtome knife. Using this procedure, I can get perfect serial sections of 10 mm mammalian embryos *in situ* within the unopened uterus. Following alcohol, material of this size would become impossibly hard long before infiltration was complete. Similarly, the yolk-laden eggs of teleost and lizard remain soft and workable when the anilin method is used.

There is another advantage of the anilin method that is important in some cases. Tissues become quite tough in $\frac{2}{3}$ anilin and anilin, and at the same time clear much more completely than with xylol. It is accordingly possible to carry out delicate dissections with ease and at the same time with little risk of accidentally injuring the tissues.

The danger-point in the process is in the transfer from anilin to xylol. Even with one or two intermediate steps the diffusion currents set up are so strong that blastocysts or thin-walled cavities of any sort are likely to collapse partially. The remedy lies, of course, in making the transition more gradual, if necessary running in the xylol by the drop method.

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SPECIAL ARTICLES

THE APPARENT EXISTENCE OF EASILY DEFLECTABLE POSITIVES

UP to the present a positive electron has always been found with an associated mass 1,850 times that associated with the negative electron. In measuring the energies of charged particles produced by cosmic rays some tracks have recently been found which seem to be produced by positive particles, but if so the masses of these particles must be small compared to the mass of the proton. The evidence for this statement is found in several photographs, three of which are discussed below.

In one instance, in which a lead plate of 6 mm thickness was inserted in the cloud-chamber, tracks of a particle were observed above and below the lead. The curvature due to the magnetic field was measurable both above and below the lead. There are the following alternative interpretations:

(1) a positive particle of small mass penetrates the lead plate and loses about two thirds of its energy; or

(2) two particles are simultaneously ejected from the lead, in one direction a positive particle of small mass, in the opposite direction an electron; or

(3) an electron of about 20,000,000 volts energy penetrates the lead plate and emerges with an energy of 60,000,000 volts, having gained 40,000,000 volts energy in traversing the lead; or

(4) the chance occurrence of two independent electron tracks in the chamber, so placed as to give the appearance of one particle traversing the lead plate.

In another instance two tracks of opposite curvature appear below the lead. The alternative interpretations are:

(1) a positive particle of small mass and an electron emerging from the same point in the lead; or

(2) a positive particle of small mass strikes the lead and rebounds with a loss in energy; or

(3) an electron of about 20,000,000 volts energy strikes the lead and rebounds with 30,000,000 volts energy; or

(4) the chance occurrence of two independent electron tracks.

In the third instance two tracks appear below the lead plate. The alternative interpretations are:

(1) a positive particle of small mass and another positive particle emerge from the same point in the lead; or

(2) a 4,000,000 volt electron rebounds from the lead producing the second track; but here a difficulty is met with, since a change in the sign of the charge would have to be assumed to take place in the rebound of the electron; or

(3) the chance occurrence of two independent tracks.

For the interpretation of these effects it seems necessary to call upon a positively charged particle having a mass comparable with that of an electron, or else admit the chance occurrence of independent tracks on the same photograph so placed as to indicate a common point of origin of two particles. The latter possibility on a probability basis is exceedingly unlikely.

The interpretation of these tracks as due to protons, or other heavier nuclei, is ruled out on the basis of range and curvature. Protons or heavier nuclei of the observed curvatures could not have ranges as great as those observed. The specific-ionization is close to that for an electron of the same curvature, hence indicating a positively-charged particle comparable in mass and magnitude of charge with an electron.

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PLASMA PHOSPHATASE IN DAIRY COWS SUFFERING FROM FLUOROSIS

FLUORINE, when included in experimental diets of animals, has been shown to cause a marked disturbance in bone and tooth metabolism. Robison[1] in 1923 showed that an enzyme capable of splitting phosphoric acid esters was instrumental in bone deposition. Kay[2] in 1930 brought forth evidence to show that the plasma phosphatase increased in such bone diseases as rickets and osteomalacia. The possibility of a change in plasma phosphatase in chronic fluorine poisoning seemed likely, and might offer a means of detecting fluorosis in cases where gross symptoms were not in evidence.

Blood samples were taken from heifers during their first lactation as follows: (1) prior to parturition; (2) near the peak of production; (3) mid-lactation or later; (4) and again near the end of lactation. Six lots of 3 animals each were available. Three of these were lots receiving no known source of fluorine, while the three remaining lots received approximately .02 per cent., .04 per cent. and .087 per cent. of the grain ration as fluorine fed as a mineral supplement in the form of raw rock phosphate. The rations were balanced as to protein. They contained ample energy and were in all respects adequate dairy rations.

The plasma phosphatase was determined by the method of Kay[3] except that pH values were determined by means of the quinhydrone electrode rather than by the colorimetric method. In all cases the animals receiving fluorine showed a distinct rise in the plasma phosphatase values over that of the control cows. In nearly all cases the values for our control animals were within the normal range of .1000 to .2000 units per cc for mature animals. Twenty-eight determinations made upon control cows gave a range of from .1168 units to .2440 units per cc with a mean value of .1763 units. The low fluorine lot gave an average phosphatase value of .2366 units per cc. The intermediate group showed a further rise in phosphatase with an average of .2751 units per cc, while the high fluorine lot varied from .2240 units to .5312 units per cc. The mean value for this lot (12 analyses) was .3366 units per cc or practically double that of the control animals. It would seem, therefore, that in cattle suffering from fluorosis the plasma phosphatase rises in proportion to the level of fluorine intake, or nearly so. Other blood constituents, such as serum calcium, inorganic phosphorus, total phosphorus, lecithin phosphorus and chlorine, remained within the normal range. There seemed to be a tendency for the serum calcium of the blood to decrease with a correspondingly slight increase in inorganic phosphorus in the animals most severely affected.

The plasma phosphatase value is apparently an excellent index of the degree of fluorosis in cattle. Not only was there a definite gradation in the plasma phosphatase content between lots, but there was a progressive rise in plasma phosphatase in the high fluorine lot coincident with a progressive severity of the gross symptoms in the cattle. These changes are no doubt explained by the increased grain required to meet the needs of lactation and subsequent higher fluorine ingestion. Cows on the high fluorine (.087 per cent. of the grain ration) gave the following average plasma phosphatase values: at parturition 0.2787 units per cc; near the peak of production, 0.3142 units per cc; mid-lactation, 0.3537 units per cc; and at the close of the first lactation, 0.4227 units per cc. In the absence of other bone diseases the plasma phosphatase in fluorosis forms a sensitive test for the toxic effects of chronic fluorine poisoning. Similar results have also been obtained with swine and rats, although the data with these species are as yet inadequate. The rise in plasma phosphatase indicates

[1] R. Robison, *Biochem. Jour.*, 17: 286, 1923.
[2] H. D. Kay, *J. Biol. Chem.*, 89: 249, 1930.
[3] H. D. Kay, *J. Biol. Chem.*, 89: 235, 1930.

a marked disturbance in bone and tooth metabolism caused by chronic fluorine poisoning. No doubt it represents on the part of the animal body an effort to maintain and deposit normal skeletal structures. There seems to be a marked stimulation to elaborate this enzyme in the case of chronic fluorine poisoning similar to that found in such bone diseases as rickets and osteomalacia.

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MICRO MOTION PICTURES OF B. SHIGAE GROWING UNDER CONDITIONS FAVORING FILTERABILITY AND LIFE CYCLE FORMS

Two of the most important problems in present-day bacteriology deal with the reality of bacterial life cycles and the existence of a minute filter-passing form of bacterial life. With a simple and inexpensive micro motion picture apparatus developed primarily for following the action of X- and ultra-violet rays on bacteria, yeasts and molds we have accumulated records of the growth of the dysentery bacillus (*B. shigae*) which bear directly on both questions.

These records, on 6,000 feet of film and covering a period of 600 hours, picture the growth of *B. shigae* in microculture during and after cultivation in ordinary beef infusion media, in media consisting exclusively of either peptones or proteins (gelatine or K media) and in media containing varying quantities of lithium chloride. They show the formation and the subsequent fate of the various abnormally shaped cells which have previously been described as typical stages in a bacterial life cycle. Hadley[1] has filtered LiCl-treated Shiga cultures and Kendall[2] has stated that the use of his K medium gives filterable stages to the related *B. typhosus*. Many photographs have been made of "filterable" cultures obtained in these ways.

Shiga bacilli when rapidly multiplying in ordinary beef infusion media are rods about 5 μ x 1 μ, but by aging these cultures or by changing their food substances it is easy to obtain all the supposed life cycle forms. Real branching occurs early in many special media; in old cultures growth practically always takes place from long filamentous cells. Except for the micrococci to be mentioned later all the other life cycle forms appear merely as stages in the adaptation of the bacillus to new and somewhat unfavorable media. When in an environment which permits of their growth and multiplication the progeny of these organisms always tend to become more and more normal in shape and size. None of them has shown any special function analogous to the more elaborate reproductive processes of the molds.

The micrococci split from certain bacilli constitute the only type of *B. shigae* growing under the conditions of these experiments which the pictures may not have completely described. These spheres, having a diameter about equal to that of the cells from which they arise, are present in nearly all cultures but are most numerous after several LiCl passages. Many appear in the photographs and some have been followed for long periods of time. No growth has ever been seen and it must be concluded that if they are alive and not mere bits of coagulated protoplasm eliminated by injured organisms, their lag period is long.

In discussing filterability through porcelain filters, a distinction may be drawn between quick and slow outgrowths, or reversions, in the filtrates. By quick reversions are meant those which show massive growth after 48–72 hours; in the slow reversions a period of weeks is required before many bacteria can be found. All efforts to get slow reversions in microculture have thus far failed. Many filtrates have been incubated and examined for periods of two and three weeks but in none of them have we been able to see or photograph anything which could properly be interpreted as alive.

More positive information has been gained concerning the quick reversions. Growth of Shiga in the K medium of Kendall[3] results in a large number of small, almost coccoid, cells. Similar dwarfed bacteria are present in LiCl cultures during those passages when they are supposedly filterable. Whenever a quick reversion was observed after filtration through a candle tested by the usual methods, it was always possible to find a few such stunted organisms in the fresh filtrate. After a more or less prolonged lag period they always grew into and multiplied as normal Shiga bacilli. This fact combined with the recent observation[4] that K medium itself aids the passage of normal bacilli through a Berkefeld filter seems to offer an adequate explanation of the quick reversions.

The details of these experiments will appear in the *Journal of Experimental Medicine.*

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[1] P. Hadley, E. Delves and J. Klimek, *Jour. Infect. Dis.*, 48: 1, 1931.
[2] A. I. Kendall, SCIENCE, 74: 129, 1931; 75: 295, 1932.
[3] A. I. Kendall, *Northwestern Univ. Bull.*, 32: 8, 1931.
[4] P. L. Varney and J. Bronfenbrenner, *Proc. Soc. Exp. Biol. Med.*, 29: 804, 1932.